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PRACTICE EXERCISES IN PHYSICS

FRANKLIN T. JONES
University School, Cleveland, Ohio

Science teachers would like to know how the actual results their efforts produce compare with their ideals. Whenever examinations or ordinary tests are given, the anticipated attainment usually compares very unfavorably with that expected. Neither teacher nor pupil knows what is the matter, nor can the superintendent or principal assist very much in diagnosing or correcting troubles. The writer of this article—undoubtedly along with many other science teachers—has given this matter considerable thought and some experiment. The results, as far as attained, are presented herewith to others with a request for co-operation in the standardization of a series of tests, first in physics and later in the other sciences.

The writing of a set of examination questions is an easy matter. The primary aim is to afford the pupil an opportunity to write and figure upon a representative group of questions and problems. He *passes* if he displays a 60 (or 75) per cent success as judged by the examiner. The preparation of a test, or series of tests, in the modern sense means, not the setting of an examination, but the statement of a standard of attainment which all normal individuals under instruction should reach with variations in speed and excellence according to natural and cultivated ability.

The point of attack selected for these first tests in physics is the numerical problem in heat. Obviously the simplest work should be tested first, proceeding step by step to the more difficult. A tentative progression in difficulty might be the following, which was, for reasons not here explained, selected by the writer.

1. Thermometers. Transformations. C. to F. and F. to C.
2. Fusion and Vaporization
3. Specific Heat
4. Heat Computations

- 5. Heat Exchange-Simple Mixtures
- 6. Heat Exchange-Complex Mixtures
- 7. Heat and Work
- 8. Expansion
- 9. Gas Laws

The first test is as follows:

Test H 1.¹ Thermometers A. Time 3:00 minutes.

1. Change	0°	centigrade to Fahrenheit.	Answer.....
2. " 1°	"	" " "	"
3. " -1°	"	" " "	"
4. " -40°	"	" " "	"
5. " 100°	"	" " "	"
6. " 40°	"	" " "	"
7. " -41°	"	" " "	"
8. " -10°	"	" " "	"
9. " 2000°	"	" " "	"
10. " -273°	"	" " "	"
No.....	Attempts.....	Right.....	Wrong.....
Time.....	Attempts.....	Right.....	Wrong.....

This test was given to a class of twenty-four boys who had completed the study of heat about two months before the date of the test, and had just passed an ordinary examination upon it. The tests were purposely deferred until after the examination, so that any satisfactory results on the latter could not be attributed to the tests. Also it was hoped thereby to get some comparisons based on the facts that these boys were studying their first science, having had no general science, physiography, or biology, and had begun the study of physics with heat, having had no mechanics, either preceding or accompanying that subject.

They were entirely unfamiliar with tests or testing, so that it was necessary to give them some explanation of what they were about to do. Without any advance warning that a test was to be given them on heat (the assigned lesson was on sound), they were

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asked by the instructor if they were willing to collect some educational data to be sent to Dr. Judd. They were told that the tests they would be asked to take were entirely new—that they were *rate* tests, just like a hundred-yard dash. The idea was attractive.

TABLE I
TEST H I. THERMOMETERS A*
(Time allowed: 3:00 minutes)

No. of Pupil	Attempts	Right	Wrong	Time to Finish	Attempts	Right	Wrong
				Min. Sec.			
1.....	4	2	2	11:00	4	2	2
2.....	10	10	0	3:50	10	10	0
3.....	2	2	0	7:15	10	8	2
4.....	3	3	0	10:15	10	7	3
5.....	2	2	0	9:30	10	2	8
6.....	6	0	6	8:05	10	0	10
7.....	7	7	0	7:40	10	10	0
8.....	5	3	2	5:50	10	6	4
9.....	(Absent)						
10.....	4	2	2	6:50	10	2	8
11.....	(Absent)						
12.....	6	3	3	6:50	10	3	7
13.....	6	4	2	6:50	10	4	6
14.....	4	4	0	9:00	10	10	0
15.....	9	9	0	4:15	10	10	0
16.....	3	2	1	8:00	10	6	4
17.....	7	7	0	4:45	10	9	1
18.....	7	6	1	5:30	10	9	1
19.....	(Absent)						
20.....	7	0	7	4:30	10	0	10
21.....	4	4	0	5:50	10	9	1
22.....	9	6	3	3:35	10	7	3
23.....	5	2	3	8:05	10	2	8
24.....	8	8	0	4:40	10	9	1
25.....	5	2	3	6:45	10	2	8
26.....	8	7	1	5:45	10	9	1
27.....	10	6	4	2:20	10	6	4
Total.....	141	101	40	234	142	92
Average....	5.87	4.21	1.66	6:32	9.75	5.92	3.83

*Test H I as here given to the class differed from the test printed above in the arrangement of the problems. The order actually used in the test was 1, 5, 2, 6, 9, 3, 8, 4, 7, 10.

“Test H I. Thermometers A” had been printed on sheets 4×5 inches. Two copies were distributed face downward to each individual. On the back of each he wrote his name and his number (each boy in the class has a number by which his position in the laboratory, apparatus, etc., are determined). One sheet was

numbered I and the other II because the instructor hoped to collect two sets of data at the same session: first, how much could be done in an allotted time; secondly, how long it would take to finish all the questions.

Since the instructor did not know how much time should be allotted, he asked the class for a method of settling upon a fair amount of time. It was finally agreed that once-and-a-half (or twice) the teacher's time for the test would be fair. While they timed him, he worked the problems. His time was one minute, fifty-five seconds (1:55), so three minutes was allowed them. He entered the time on the blackboard at intervals of ten seconds, and, at three minutes, said, "Change over"; after which further results were entered on sheet II.

The results are given in Table I on page 343.

Translating the results of Table I into percentages we find: in three minutes 58.7 per cent of all the questions were attempted and 42.1 per cent of all were correct; in 6:32 minutes (the average time to complete) 97.5 per cent of all the questions were attempted and 59.2 per cent of all were correct. Put in a different way—correct attempts were 71.6 per cent of those attempted in three minutes, and 60.7 per cent of those attempted in 6:32 minutes.

About two weeks later, after other tests had been given, Test H 1 was repeated as printed, with the following results:

	Time Allowed, 3:00 Minutes	Time to Finish, 3:08 Minutes
Attempts.....	8.77	9.75
Right.....	7.41	8.27
Attempts.....	87.7 per cent of whole	100.0 per cent of whole
Right.....	74.1 per cent of whole	82.7 per cent of whole
Right.....	84.6 per cent of attempts	82.7 per cent of attempts

The class was asked to indicate to how many and which problems answers were remembered. Except Nos. 1 and 5, with an occasional No. 4, answers were not remembered. The question was also asked whether the rearrangement was advantageous, viewing the list as a test. A very few members of the class thought that rearrangement made no difference; the great majority believed that the rearrangement was advantageous.

Evidently practice on this test, in spite of a rearrangement that made the test more difficult, showed beneficial results, not only in a marked increase in accuracy, but in a great increase in speed. During these tests absolutely no instruction was given on the subject of heat. Regular lessons on sound were recited each day. The reader can readily observe the effects of practice by consulting Table II. A test, when repeated, was given again after other tests had intervened.

Tests have also been given as follows:

Test H 2. Thermometers B. Time 4:30 minutes.

1.	Change	212°	Fahrenheit	to	centigrade.	Answer.....
2.	"	33°	"	"	"	"
3.	"	0°	"	"	"	"
4.	"	-10°	"	"	"	"
5.	"	40°	"	"	"	"
6.	"	2,000°	"	"	"	"
7.	"	10°	"	"	"	"
8.	"	-1°	"	"	"	"
9.	"	100°	"	"	"	"
10.	"	31°	"	"	"	"
11.	"	32°	"	"	"	"
12.	"	-40°	"	"	"	"
No.....	Attempts.....	Right.....	Wrong.....			
Time.....	Attempts.....	Right.....	Wrong.....			

Test H 3. Fusion. Time 2:30 minutes.

How many calories of heat are absorbed when

1. 1 gram of ice melts? Answer.....
2. 1,000 grams " " melt? "
3. 40 " " " " "

How many calories of heat are liberated when

4. 1,500 grams of water freeze? Answer
5. 500 " " " " "
6. 1 gram " " freezes? "

How many B.T.U. of heat are absorbed when

7. 10 pounds of ice melt? Answer.....
8. 1 pound " " melts? "
9. 600 pounds " " melt? "

How many B.T.U. of heat are liberated when

10. 2,500 pounds of water freeze? Answer.....
11. 750 " " " " "
12. 1 pound " " freezes? "

No..... Attempts..... Right..... Wrong.....
 Time..... Attempts..... Right..... Wrong.....

Test H 4. Vaporization. Time 2:30 minutes.

How many calories of heat are absorbed when

1. 1 gram of water vaporizes? Answer.....
2. 10 grams " " vaporize? "
3. 200 " " " " " "

How many calories of heat are liberated when

4. 1 gram of steam condenses? Answer.....
5. 20 grams " " condense? "
6. 300 " " " " " "

How many B.T.U. of heat are absorbed when

7. 1 pound of water vaporizes? Answer.....
8. 40 pounds " " vaporize? "
9. 3,000 " " " " " "

How many B.T.U. of heat are liberated when

10. 1 pound of steam condenses? Answer.....
11. 50 pounds " " condense? "
12. 1,000 " " " " " "

No..... Attempts..... Right..... Wrong.....

Time..... Attempts..... Right..... Wrong.....

Test H 5. Specific Heat. Time 3:00 minutes.

How many calories of heat are absorbed when

1. 1 gram of water (sp. ht. 1) changes 1° C.? Ans....
2. 40 grams " " " change 10° C.? " ...
3. 90 grams " " " " 40° C.? " ...
4. 1 gram " copper (sp. ht. .092) changes 1° C.? " ...
5. 80 grams " " " change 20° C.? " ...
6. 10 grams " lead (sp. ht. .030) " 30° C.? " ...
7. 1 gram " steam (sp. ht. .477) changes 10° C.? " ...
8. 20 grams " " " change 50° C.? " ...
9. 1 gram " ice (sp. ht. .505) changes 60° C.? " ...
10. 70 grams " " " change 10° C.? " ...

No..... Attempts..... Right..... Wrong.....

Time..... Attempts..... Right..... Wrong.....

Test H 8. Heat Exchange-Simple Mixtures A. Time 7:00 minutes.

1. How much water at 10° C. will be required to cool 100 grams of water at 90° C. to 60° C.? Ans.....

2. What must be the temperature of 60 grams of water to warm 80 grams of water from 20° to 30° C.? Ans.....

3. How much water at 30° C. will be required to warm 2,000 grams of iron (sp. ht. .109) from 15° to 25° C.? Ans.....

4. What must be the temperature of 300 grams of copper (sp. ht. .092) if, when put into 200 grams of water at 20° C., the temperature rises to 25° C.? Ans.....

5. How many grams of ice-cold water must be poured into a tumbler weighing 300 grams to cool it from 60° C. to 20° C. (sp. ht. glass 0.2)? Ans.....

No..... Attempts..... Right..... Wrong.....

Time..... Attempts..... Right..... Wrong.....

TABLE II
SUMMARY—TESTS H 1-5 AND 8

No. of Test	No. Tested	Title	No. of Questions	Time Allowed	Attempts	Percentage Attempted	Right	Percentage of Attempts Right	Average Time to Complete	Attempts	Percentage Attempted	Right	Percentage of Attempts Right
H 1	24	Thermometers C. to F.	10	3:00	5.87	58.7	4.21	71.6	6:32	9.75	97.5	5.92	60.7
H 1	22	Thermometers C. to F.	10	3:00	8.77	87.7	7.41	84.6	3:08	10.00	100.0	8.27	82.7
H 2	24	Thermometers F. to C.	12	4:30	9.04	75.3	6.79	74.0	6:12	11.58	96.5	8.42	72.7
H 2	22	Thermometers F. to C.	12	4:30	7.86	65.5	6.50	82.7	6:20	11.96	99.7	9.64	80.6
H 2	24	Thermometers F. to C.	12	4:30	9.75	81.2	7.92	81.2	5:06	12.00	100.0	9.56	79.6
H 3	23	Fusion	12	2:30	6.60	55.7	5.83	87.1	4:59	8.04	75.3	6.13	70.2
H 3	22	Fusion	12	2:30	11.40	95.0	11.10	97.3	1:48	11.73	97.7	11.41	97.3
H 3	25	Fusion	12	2:30	11.40	95.0	10.60	92.7	2:15	12.00	100.0	11.12	92.6
H 4	22	Vaporization	12	2:30	11.90	99.2	10.10	84.9	2:02	12.00	100.0	10.20	85.1
H 5	23	Specific Heat	10	3:00	7.50	75.0	6.80	90.6	3:15	100.00	100.0	9.00	90.0
H 8	25	Heat Exchange—Simple Mixtures	5	7:00	2.92	58.4	0.88	30.1	8:38	4.00	80.0	1.24	31.0
H 8	19	Heat Exchange—Simple Mixtures	5	7:00	3.58	71.6	1.84	51.3	7:37	3.94	78.8	1.94	49.3

In Table II results from these tests are tabulated. Starred tests were rearranged like Test H 1 before being given the second time. In Test H 2 the rearrangement slowed the test a few seconds. Repetition of the rearranged test a week later showed an increase in speed and in number done, but a slight decrease in percentile accuracy. Rearrangement of Test H 3 did not prevent a marked increase in speed as well as in percentile accuracy.

Test H 8 was given out of order to find out, if possible, whether a break in logical continuity as well as a marked increase in complexity of operations would be reflected in the result. The low values indicate either that this test is unsuitable (if so, most school examinations and all college-entrance examinations are not suited to the capacity of pupils), or else that it had not been preceded by adequate instruction and preparation.

The time allotted to each test was determined as explained for Test H 1 by doubling the teacher's time. No one of these tests should take more than fifteen or twenty minutes from the recitation period, including the time for correcting them and entering the data on a sheet like Table I, which can be prepared in advance on an ordinary sheet of cross-section paper.

The writer asks teachers the country over to co-operate with him by trying these tests under the conditions outlined above. It is hoped that a sufficient variety of schools and classes may be tested so that the tests may be *standardized* both in time and content. Possibly it may add zest to the trials if classes are asked to go against the figures given in Table II for boys in University School without, of course, telling the classes in advance the figures against which they are competing. By such a co-operative plan the preparation of satisfactorily standardized tests will be greatly hastened. In anticipation of such co-operation the name "Union Science Tests" has been adopted.